

Be/X-ray Binaries with LOFT

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NASA/MSFC

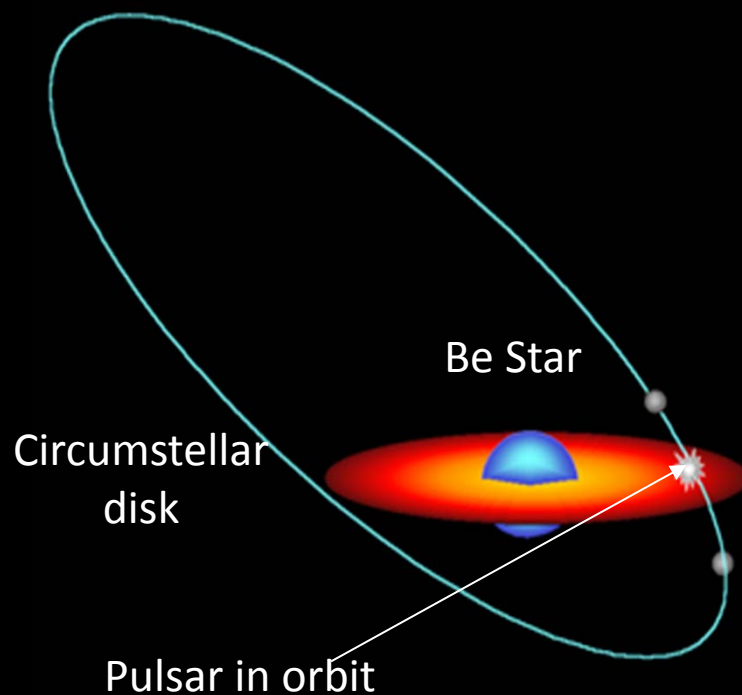
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Outline

- Yellow book science
 - Cyclotron Features and pulse to pulse variability
 - Centrifugal inhibition
 - Small Magellanic Clouds
- Importance of coordinated optical/IR observations
- Other open questions
- Summary

Be X-ray Binaries

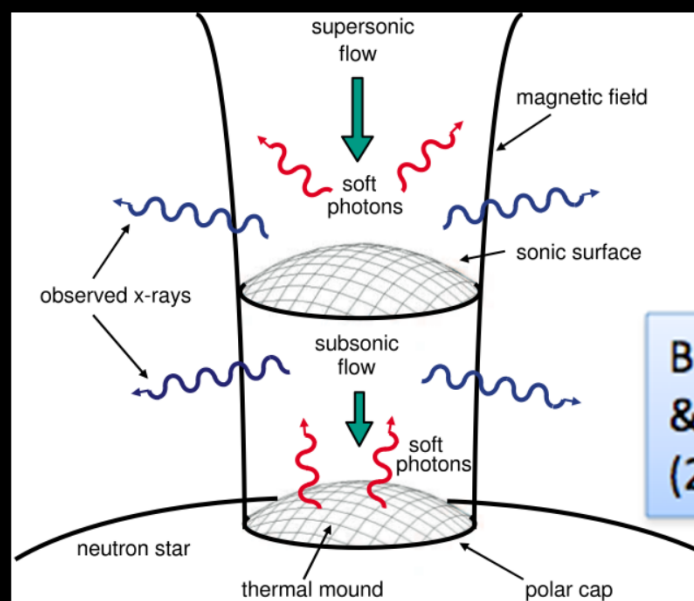


- High B-field 10^{12-13} G
- Be Star surrounded by decretion disk
- Spin periods 1-1000s
- Elliptical orbits with periods of 10-1000 d
- Two classes of outbursts
 - Normal/Type I (orbitally modulated)
 - Giant/Type II (very bright)
 - Also faint persistent systems
- Most numerous HMXB
 - ~80 in Milky Way
 - ~60 in SMC
 - ~12 in LMC

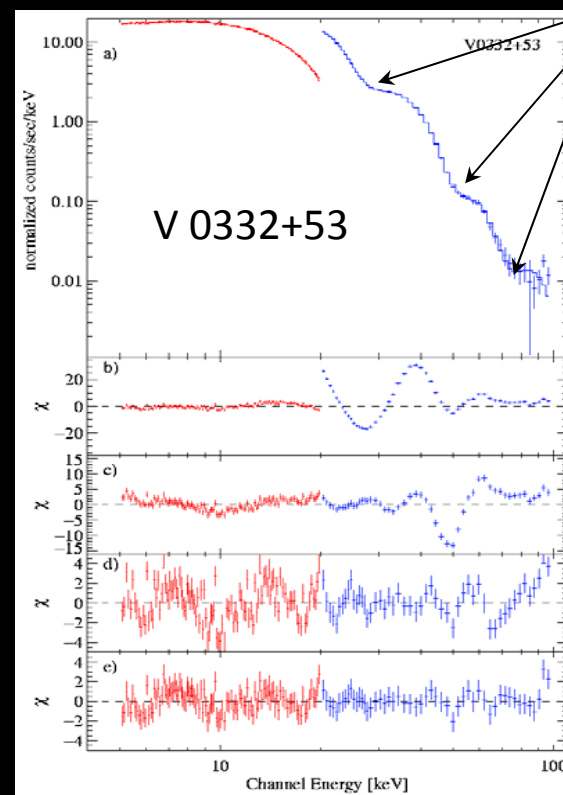
Cyclotron Scattering Absorption Features

- Electrons interact with the magnetic field, producing line-like emission at the cyclotron energy.
- To be observed in X-rays, a B-field of 10^{12-13} G is required
- Discovered by Trumper (1977, 1978) in Her X-1 spectra

$$E_n = m_e c^2 \frac{\sqrt{1 + 2n(B/B_{\text{crit}}) \sin^2 \theta} - 1}{\sin^2 \theta} \frac{1}{1 + z},$$



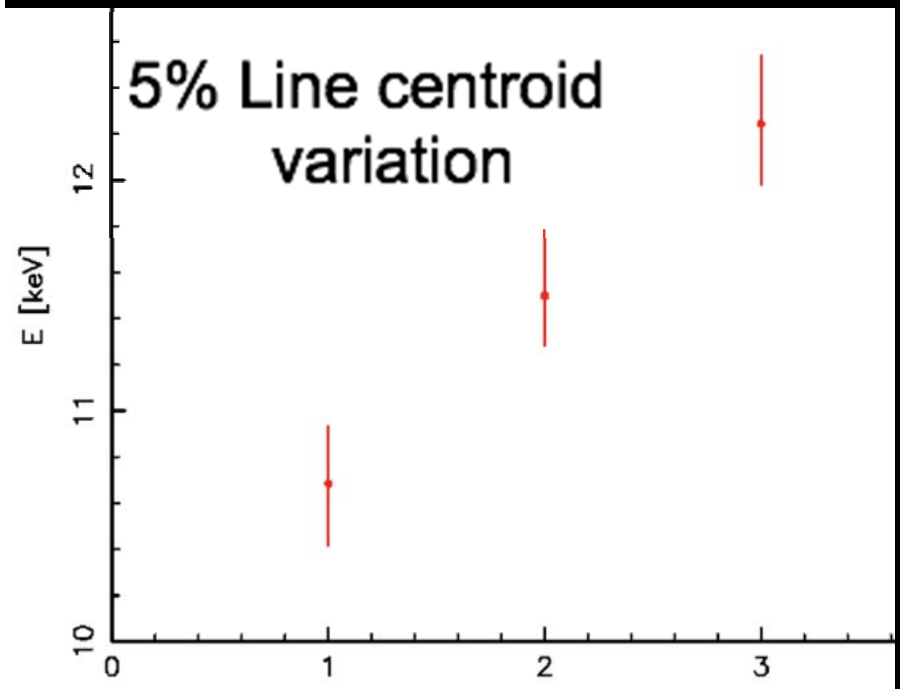
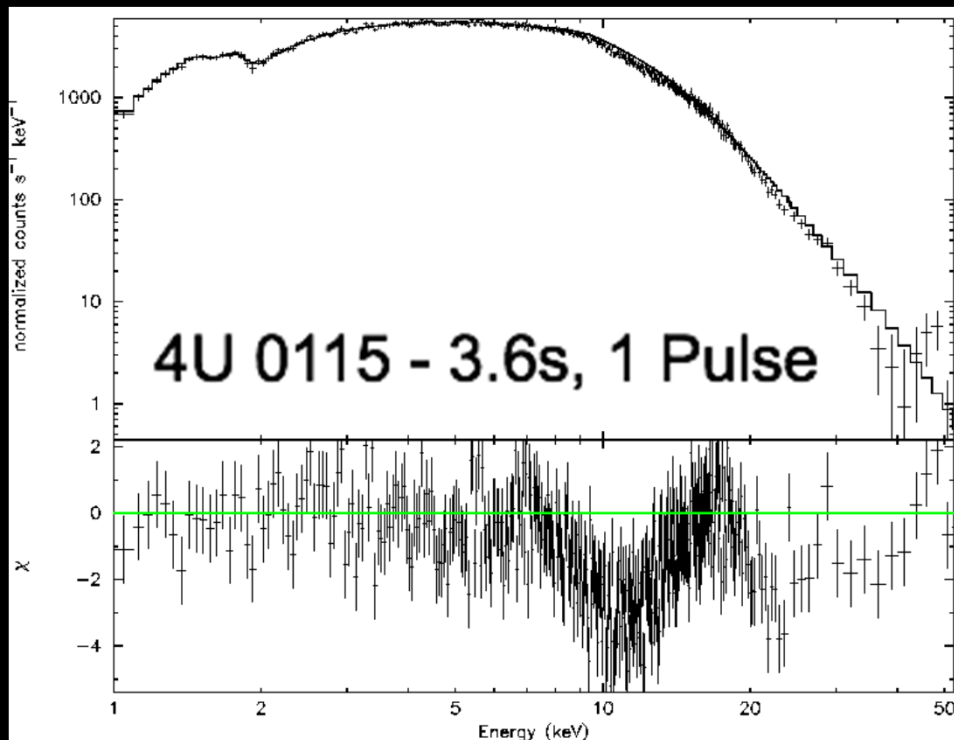
Becker
& Wolff
(2007)



Kreikenbohm et al. (2005)

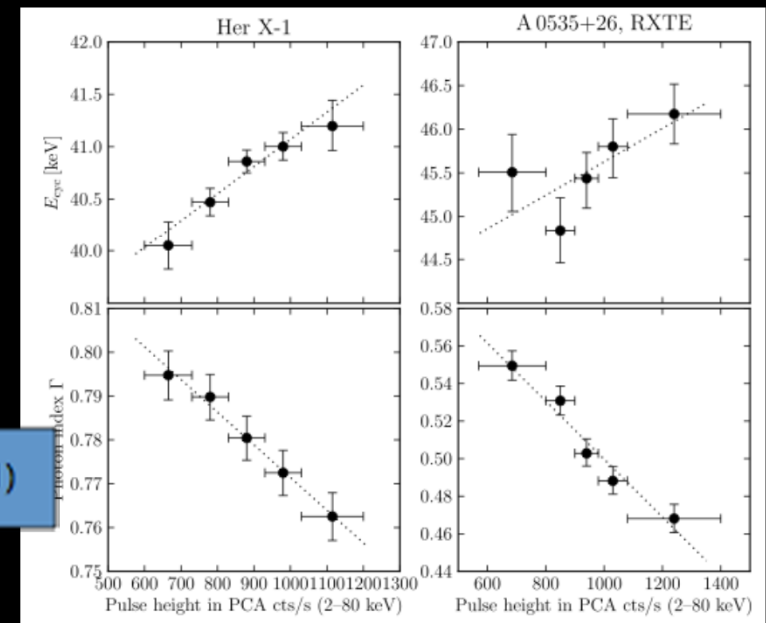
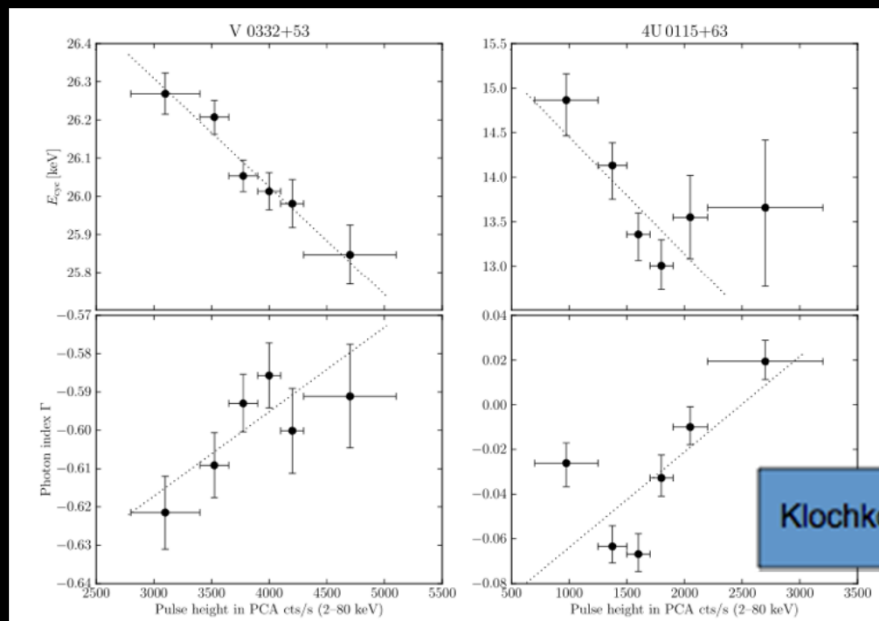
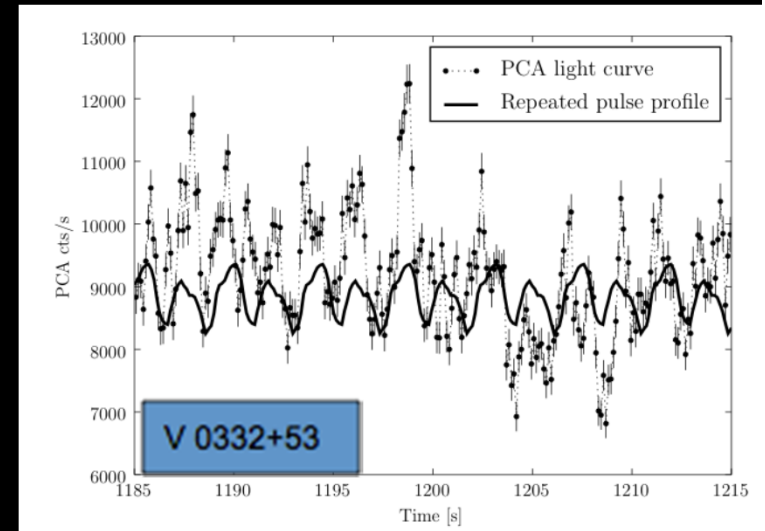
Pulse-to-pulse variations of cyclotron energy with LOFT

- Column is “breathing” on sub-pulse timescale
- With LOFT, single pulses have high enough statistics to derive cyclotron energy variations of a few percent



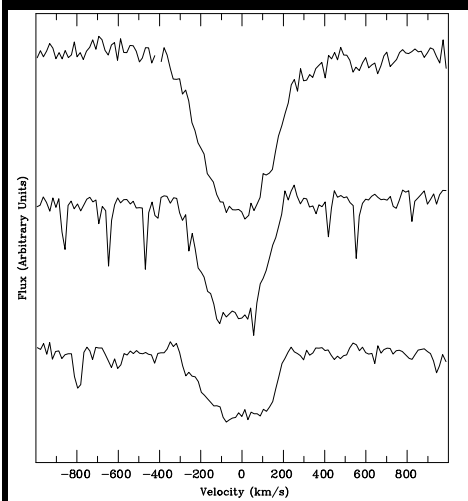
Pulse-to-pulse variability

- Consistent with long-term average spectral variations
- Two accretion regimes:
 - Local sub- and super-Eddington

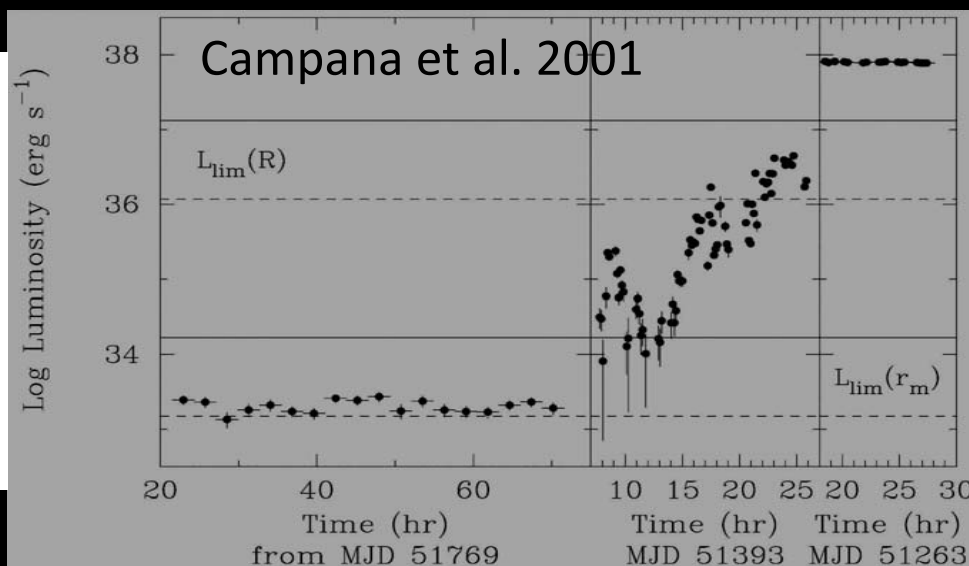
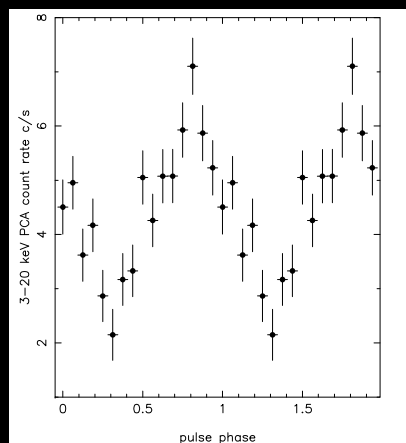


Centrifugal Inhibition of Accretion

- Observe X-ray binaries to $L \sim 10^{33} \text{ erg s}^{-1}$
- Pulsations detected at $L < 10^{34} \text{ erg s}^{-1}$ for A0535+26 (Negueruela et al. 2000), 4U 1145-619, and A1118-615 (Rutledge et al. 2007)
- $L_{\text{cutoff}} \approx 2 \times 10^{38} (\mu/10^{30} \text{ G cm}^3)^2 (P/1\text{s})^{-7/3} \text{ erg s}^{-1}$



A0535 +26 Negueruela et al. 2000



Continued Monitoring of SMC with LOFT

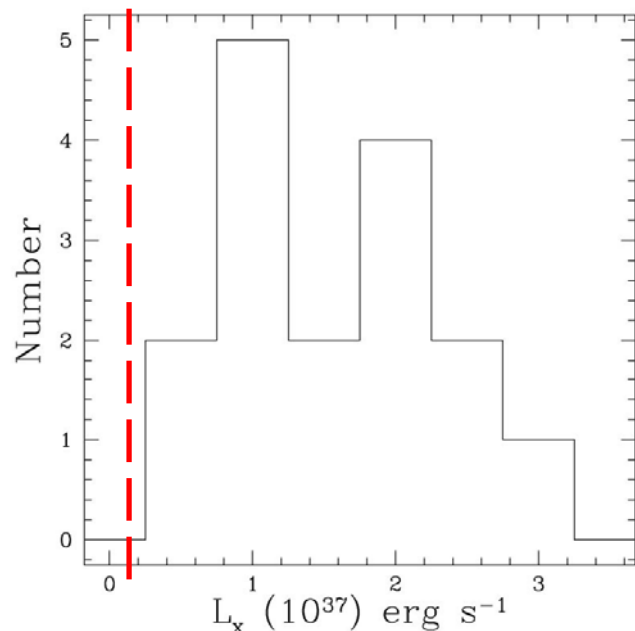


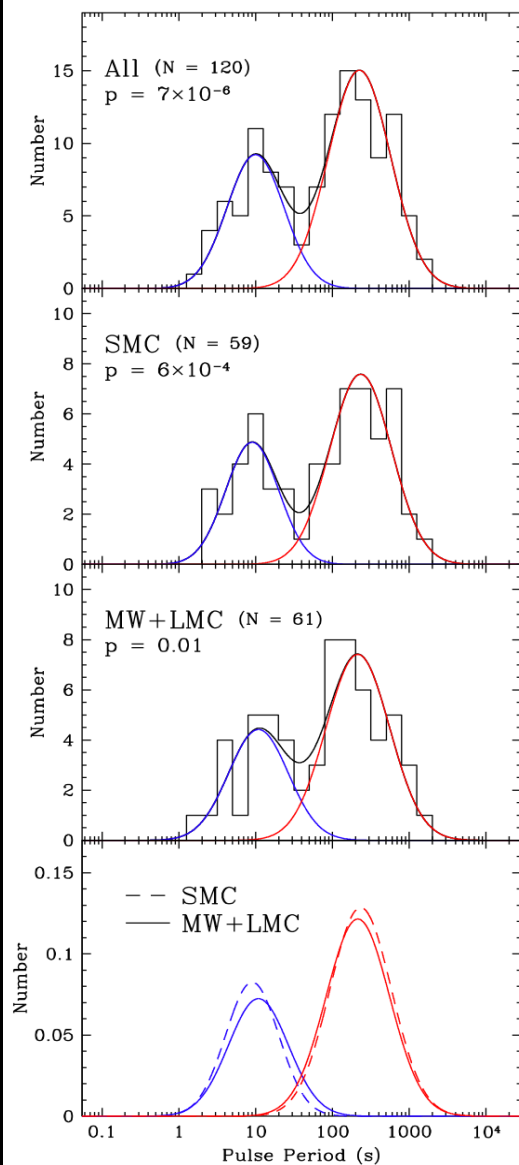
Figure 4. The histogram of the estimated peak X-ray luminosities for the outbursts discussed in this work. The exceptionally large outburst from SXP2.37 is excluded from this plot.

- 13 years of weekly monitoring with RXTE PCA
- Plotted luminosities are typical of “normal” outbursts (once per orbit)
- Giant outbursts are a factor of 10 brighter, but much rarer
- LOFT WFM can detect outbursts $>0.1 \times 10^{37} \text{ erg s}^{-1}$ (red line) in a few days, similar to RXTE PCA sensitivity
- LOFT LAD can detect outbursts $>0.01 \times 10^{37} \text{ erg s}^{-1}$ in ~ 10 ks, order of magnitude fainter than RXTE PCA
- Constrain M using Pdot Luminosity correlation

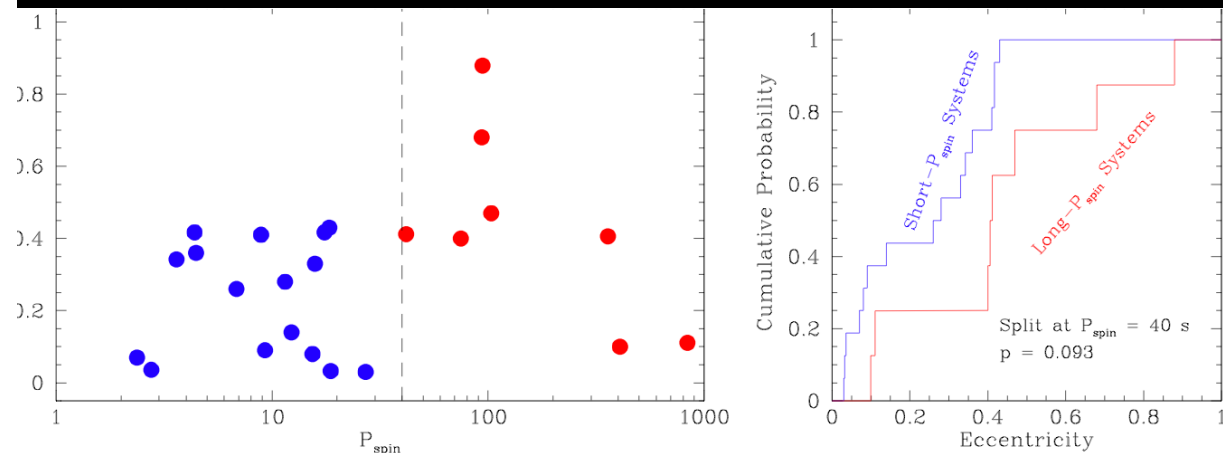
Coe, McBride, & Corbet, 2010, MNRAS, 401,252

Two populations of Be X-ray Binaries?

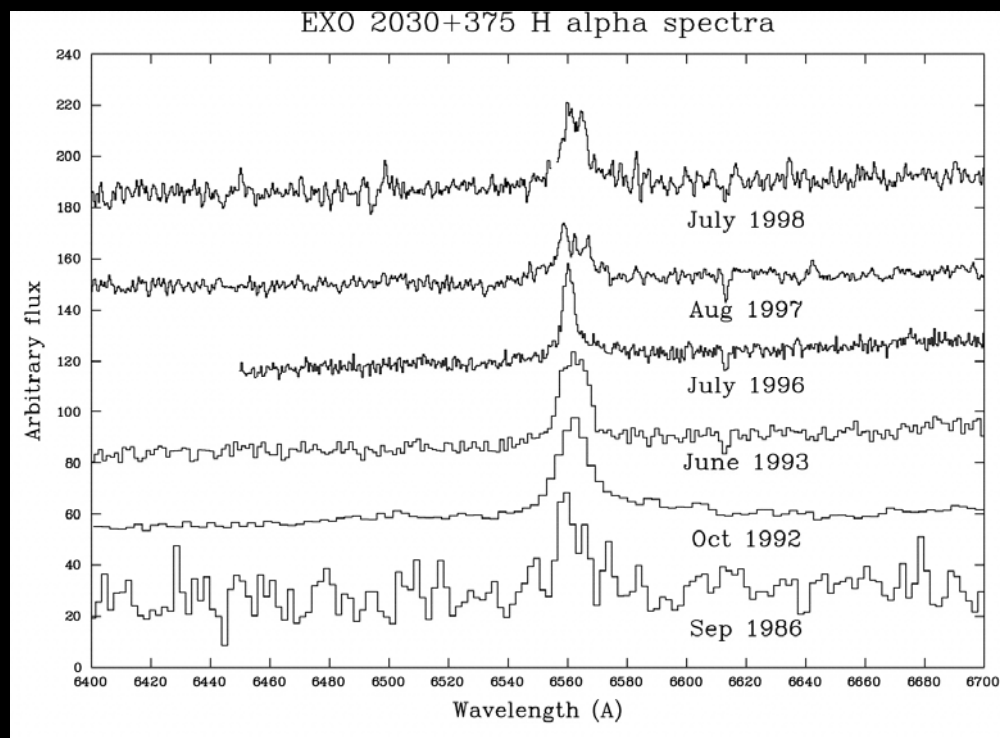
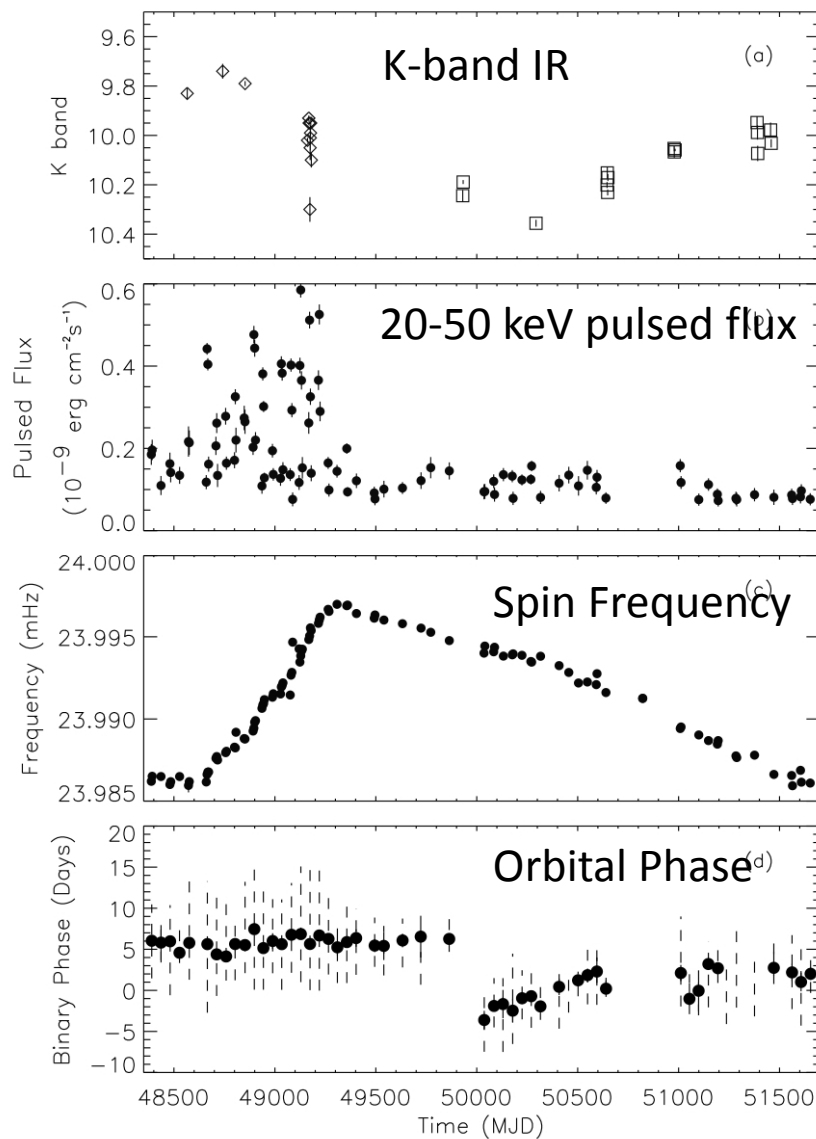
- Bimodal distribution consistent between SMC and MW+LMC
- Not predicted by SN models
- Iron-core collapse model predicts high eccentricities, e-capture model predicts low eccentricities



Knigge, Coe, & Podsiadlowski 2011



Importance of Multiwavelength Monitoring



Summary

- LOFT will enable pulse-to-pulse of cyclotron features for the first time.
- LOFT will enable studies of outbursts, quiescence, and outburst onsets.
- LOFT will continue monitoring the SMC, extending RXTE an order of magnitude fainter.
- To fully understand LOFT's observations of Be X-ray binaries, supporting optical/IR observations are crucial.